# USEFULNESS OF THERMAL INFRARED AND RELATED IMAGERY IN THE EVALUATION OF AGRICULTURAL RESOURCES

*An Exploratory Study*



*By*

ROBERT N. COLWELL
JOHN E. ESTES
CLIFFORD E. TIEDEMANN
JAMES E. FLEMING

*A report of research performed by personnel of the University of California for the*

Natural Resources Program,
Office of Space Sciences and Applications,
National Aeronautics and Space Administration
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No. 12-14-100-8316(20)

**VOLUME II**



*30 September 1966*

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# PREFACE

The application of remote sensing technology to the inventory and analysis of such important agricultural resources as cultivated crops, livestock, soils and water provides a useful tool for the proper allocation of these resources by the agricultural land manager. Volume II, LIVESTOCK, SOIL AND WATER, demonstrates the usefulness of aerial photography in the evaluation of these resources, and is one of two volumes prepared for this research study entitled, "The Usefulness of Thermal Infrared and Related Imagery in the Evaluation of Agricultural Resources". The first part of Volume II discusses previous and current research on the use of remote sensing for livestock inventory, while the second portion presents a combined discourse on similar research on the inventory of soil and water resources.

Volume I, CULTIVATED CROPS, deals exclusively with the applications of remote sensing technology to the inventory of cultivated crops.

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## ABSTRACT

Multispectral imagery of selected test areas in California was studied to determine its usefulness in the inventory and analysis of the livestock, soils and water resources. Part I of this volume presents optimum specifications and recommendations for a reliable inventory of livestock in California through the use of conventional aerial photography. In doing so, the season for obtaining useful imagery, the optimum scale of imagery and the usefulness of each film or image type is illustrated and discussed. Additionally, a comprehensive series of selective aerial photo identification keys, accompanied by feasibility ratings, is included to facilitate the inventory of animal types and animal breeds.

Part II discusses the applications of remote sensing technology for the inventory and analysis of the soil and water resources. A discussion of the adaptiveness and usefulness of a multispectral approach to the evaluation of these resources is presented with selected illustrations. Potential gains that can be obtained from further studies of the application of multispectral imagery to the soil and water resources are also discussed.

Author

ACKNOWLEDGEMENTS

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Presentation of the material contained in this report has been made possible through the cooperative efforts of several individuals and organizations. Among the students of the University of California at Berkeley who rendered vital service in the collection of ground truth, interpretation of photos, and the compilation of the photo interpretaion keys used in this study were Gene Thorley, Dave Carneggie, Jerry Lent, Ed Roberts, Tom Tracy, Cindy Graham, Ruth Ormondroyd, Eric Janes, John Thomas, and Larry Pettinger. Assistance from personnel of the Department of Agronomy on the Davis campus of the University of California in the identification of crop types and the evaluation of crop yields is also greatly appreciated.

In addition, grateful acknowledgement is given to personnel of Cartwright Aerial Survey, Incorporated, who took the aerial photography to precise specifications so that valid comparisons could be made of photo images obtained by using various film-filter-scale combinations. Much appreciated help in obtaining spectrozonal imagery using a multi-sensor system with eighteen scanner channels was received from the Infrared Optical Sensor Laboratory of the University of Michigan. Lastly, thermal infrared imagery of the Imperial Valley of California was obtained through the courtesy of HRB-Singer Incorportated, of State College, Pennsylvania.

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## VOLUME II - LIVESTOCK, SOILS AND WATER

## INTRODUCTION

Managers of agricultural lands are continually in search of improved techniques to assist them in the management of their agricultural resources. To help fulfill this need, the Report seeks to explore the usefulness of thermal infrared and related imagery in the evaluation of agricultural resources.

Before demonstrating some of the pertinent uses of aerial photography for agricultural resource management, it is helpful to recognize the phases which intelligent management entails. These are: (1) inventory (determining the quantity and quality of each agricultural resource in each portion of the area that is to be managed; (2) analysis (developing a plan based on this inventory, whereby each resource available in the area can be manipulated so as to provide the maximum benefit for mankind); (3) operation (the day-to-day implementation of the management plan).

In this Report the agricultural resources are organized into three major groups: Cultivated Crops, Livestock, and Soil and Water. Volume I discusses the Cultivated Crops section of this Report. This volume contains the discussion on Livestock and Soil and Water.

The Livestock section of the Report follows a format similar to that of the Cultivated Crop section, beginning with a discussion of the usefulness of aerial photography for the inventory and analysis of livestock on thermal infrared and conventional photography. It is followed by a series

of keys with feasibility ratings for livestock identification as to animal type and animal breed.

The Soil and Water portion discusses the usefulness of aerial photography for the analysis of these resources, placing most emphasis on the feasibility of detecting differences in soil moisture and soil conditions from an interpretation of remote sensing imagery.

Care was taken to concentrate the major part of this exploratory study on a rather small number of livestock classes and geographic localities. This was done so that each could be studied with sufficient detail to permit the drawing of valid conclusions as to the feasibility of its being inventoried and analyzed from aerial photographs. Consequently, not all of the crops present in the study were investigated.

Because of the great number of variables inherent in a study of this kind, most of the photography was taken with a single photo system, the Zeiss precision aerial camera, which has a focal length of 6 inches and a negative size of 9 x 9 inches. Thus, conclusions as to the optimum specifications for the inventory and analysis of agricultural resources are based mainly on the Zeiss photography. The Zeiss camera provides an average resolution on the negative of 40 lines per millimeter, which was well preserved on the prints (even in shaded areas) by LogEtronic printing.

In addition, a great many film-filter combinations were employed in this study. Spectrozonal images in eighteen scanner channels, as well as conventional images were obtained especially for the study. The conventional photography included panchromatic, Aerographic Infrared (near infrared), Aerial Ektachrome and Ekta Aero Infrared (the infrared-sensitive Aerial Ektachrome) films. The appropriate Wratten filters were used when needed.

# VOLUME II

## PART I

### LIVESTOCK

THE USE OF AERIAL PHOTOGRAPHY FOR THE INVENTORY AND ANALYSIS OF LIVESTOCK

The managers of various agricultural resources realize that accurate inventories are necessary for the intelligent management of these resources. This is as true for livestock as it is for cultivated and timber crops. Major emphasis of this part of the study is on livestock inventories.

Among the inventory data desired by livestock managers are livestock counts in each field, by kind of animal (e.g., cattle, sheep), use (e.g., dairy cattle, beef cattle), breed, sex, age, and vigor. In addition they need an estimate of each factor affecting the animal-carrying capacity of an area, including the amount, palatability, accessibility, and nutritive value of each species of forage; the location and state of repair of corrals and livestock fences; and the location of stock-poisoning plants, noxious weeds, springs, salt grounds, stock-watering places, rodent concentrations, highly erodible sites, and areas in need of reseeding.

Preliminary aerial photographic tests of livestock detectability were made by the Vidya Division of Itek Corporation over pastureland near Milpitas, California, at flight altitudes of 5,000, 10,000, 15,000, and 20,000 feet, with both high and low sun angles, using a high-resolution panchromatic film and a light red filter. Interpretation of this photography indicated that both cattle and sheep could be detected in aerial panoramic photographs at scales as small as 1/20,000. Reliable age and sex distinctions were not possible at this scale, however, and in the words of the Vidya report, "some cattle probably were overlooked." Because accurate on-the-ground cattle counts at the time of photography were lacking, no more definite statements could be made.

Simulated operational flights were then made by Vidya covering areas in Utah, Colorado and Wyoming which the Department of Agriculture considered

representative for a feasibility study on the making of livestock inventories. In these flights 27 passes were made over 11 flight lines, mostly at an altitude of 12,000 feet above the terrain. The photographic flight lines for this 1/12,000 scale coverage totaled 190 linear miles and covered an area of nearly 700 square miles. Most of this photography was flown between the hours of 8:00 a.m. and 10.00 a.m. in order to combine the advantages of clear atmosphere, optimum light angle for interpretable shadows of livestock, and visibility of animals in the open during the cool of the day. (Animals seek shade in the middle of the day and thus may be hidden from view on aerial photos taken at that time).

By means of Vidya's large screen rear-projection equipment, negatives obtained from this photography were projected for viewing and interpretation. Livestock counts were made from the projected images in several hundred areas, including dairy feed lots and pastures, family-type barnyards, and range areas, on a total of 376 exposures. Where possible, the animals counted were tabulated by type, breed, sex, age and environment.

In the Vidya study, efforts were next directed toward checking the livestock counts against those made on the ground by Department of Agriculture field personnel and discovering the causes of discrepancies. Although the correlations between photo interpretation and ground sampling were considered satisfactory for a basic judgment of feasibility, Vidya concluded that denser and more precise ground sampling would be necessary to make a detailed assessment of reliability, and particularly to establish a valid statistical confidence level.

Despite these limitations in the Vidya study, the authors of the report concludes: (1) HyAc panoramic photography at scales of 1/7,000 to 1/8,000 ia adequate for a livestock survey program. (2) Photographic passes made

at these scales have been successfully used for detection and identification of animals by type and often by use class and breed. (3) The best black-and-white film-filter combination for use in making livestock inventories appears to be one that combines a high-resolution panchromatic film with a filter that eliminates blue, blue-green and red light while transmitting green, yellow and orange light. (4) Correct head counts can often be made on photography at 1/12,000 or even smaller scale. (3) Within the total head count, however, distinctions of age and breed, still less sex, are not consistently reliable at 1/12,000. (6) The primary photo image characteristics that are useful in making livestock inventories are animal shape, size, color or tone, shadow, and site. The potential usefulness of these characteristics is discussed in detail in the Vidya report.

The encouraging, but somewhat tentative conclusions drawn from the Vidya studies indicated that additional research might well be performed on the usefulness of aerial photography in making livestock inventories. Such additional studies should be well fortified with ground truth, obtained, whenever possible, at the instant of photography. It seemed probable that the completeness and accuracy of livestock interpretation made on small-scale aerial photos might be improved if some basic studies were to be performed with large-scale simulated aerial photos. Such photos might be taken under carefully controlled conditions, from the top of a water tower, for example, with representative livestock on display near the base of the tower. The near-vertical photos thus obtained would permit the photo interpreter to make a realistic and detailed analysis of each animal image and of the shadow cast by the animal. Many photos of this livestock array could be taken from the tower quite economically, at various sun angles, with various film-filter combinations, and with varying but precisely known amounts of stereoscopic

parallax. Furthermore, the animals composing this array could be made to assume various stances representative of those encountered on operational aerial photos. It seemed likely that a study of this photography and of actual aerial photography obtained of the same target array at the same time would indicate the most suitable film-filter combination and the best time of day for photographing livestock. The aerial and water tower photography would also contain valuable examples for the construction of photo interpretation keys to livestock.

Once this work had been performed, simulated operational photography of representative range and pasture lands could be flown to optimum specifications. Then, through use of the photo interpretation keys, livestock inventories could be attempted on this photography under truly optimum conditions. It seemed necessary to strive for such conditions because the Vidya studies had indicated that the aerial photo interpretation of livestock is, at best, a difficult task.

The two photos shown in Figures 1 through 12 are representative of the more than 200 vertical photographs taken by the present investigators from the catwalk of a water tower on the Davis campus of the University of California. They illustrate how livestock of various kinds, breeds, sizes and sexes appear in the near-vertical view when photographed from an altitude of 150 feet with a camera having a focal length of six inches. Of these two photos shown in Figure 9, the one on the top, which was taken with infrared film and an 87C filter, permits the photo interpreter to distinguish between Hereford cattle and cattle which are the offspring of a Hereford-Angus cross. Tones registered by the dark parts of the labeled animals permit them to be differentiated as to breed. On the bottom member of this pair of photos, however (taken with panchromatic film and a minus-blue filter), such tonal

## LIVESTOCK IDENTIFICATION IN RELATION TO SCALE, FILM, AND FILTER


Scale 1/150; Ektacolor Film; No Filter

Figure 1: Color photography of target array taken from the catwalk of the Davis water tower.

Water tower, Davis, California
Catwalk is approximately 150 feet above the ground.

Figure 2: Terrestrial ground photo illustrating test area at Davis, California.

**Film:** Ektachrome

**Filter:** None

**Camera:** Speed Graphic with a 6" focal length

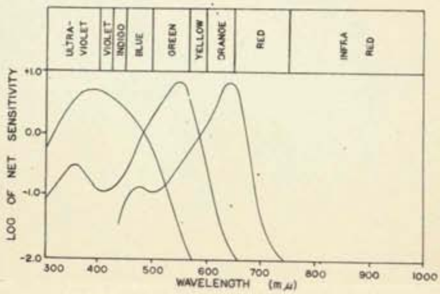



Figure 3: Multiband photography taken from the catwalk of the Davis water tower.

**Film:** Camouflage Detection

**Filter:** Wratten 12+EF2200

**Camera:** Speed Graphic with a 6" focal length

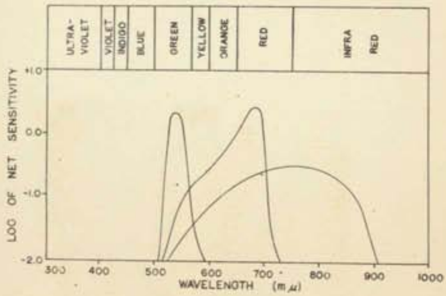



Figure 4: Multiband photography taken from the catwalk of the Davis water tower.

Film: Infrared

Filter: Wratten 87C

Camera: Speed Graphic with a 6" focal length

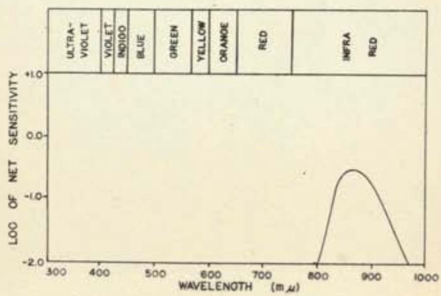



Figure 5: Multiband photography taken from the catwalk of the Davis water tower.

**Film:** Panchromatic (Tri-X)

**Filter:** Wratten 12

**Camera:** Speed Graphic with a 6" focal length

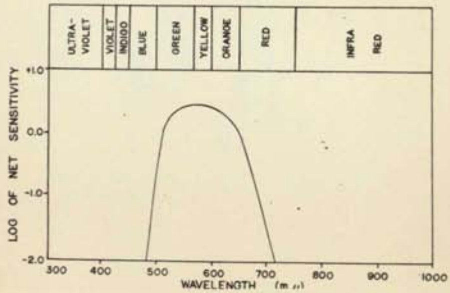



Figure 6: Multiband photography taken from the catwalk of the Davis water tower.

<u>Film</u>: Panchromatic (Tri-X)

<u>Filter</u>: Wratten 61

<u>Camera</u>: Speed Graphic with a 6" focal length

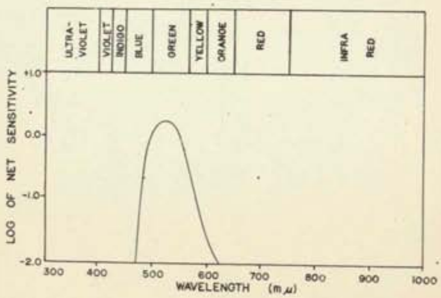



Figure 7: Multiband photography taken from the catwalk of the Davis water tower.

**Film:** Panchromatic (Tri-X)

**Filter:** Wratten 90

**Camera:** Speed Graphic with a 6" focal length

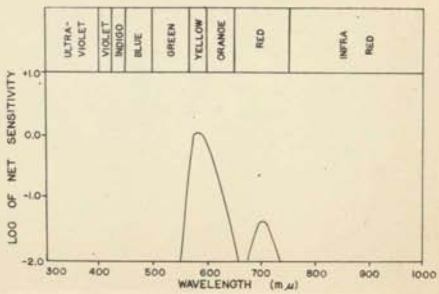



Figure 8: Multiband photography taken from the catwalk of the Davis water tower.


Scale 1/300; Infrared Film; Wratten 87C Filter


Scale 1/300; Panchromatic Film; Wratten 12 Filter

Figure 9: Contrasting tone signature allows the photo interpreter to separate Hereford cattle (A) and Hereford-Angus cross cattle (B) on infrared film with an 87C filter (upper photo). Such tonal separations cannot be made on photographs taken with panchromatic film with a minus-blue (Wratten 12) filter, as shown in lower photo.


Scale 1/300; Orthochromatic film; Wratten 18 Filter


Scale 1/300; Panchromatic Film; Wratten 12 Filter

Figure 10: Contrasting tone signature allows the photo interpreter to separate shorn sheep (A) and unshorn sheep (B) on orthochromatic film with an 18A filter (upper photo). Such tonal separations cannot be made on photographs taken with panchromatic film with a minus-blue (Wratten 12) filter, as shown in the lower photo.

separation cannot be made. This observation is representative of the many which can be made from photos such as these, when seeking to determine the most suitable film-filter combination for use in livestock inventories. The films used in taking the water tower photos included panchromatic, orthochromatic, infrared, negative color, Ektachrome, and Ekta Aero Infrared; all filters used were in the Wratten series and were numbered 2C, 12, 18A, 29, 30, 35, 47B, 61, 87B, and 89B.

Most of the aerial photos of livestock appearing in this report have been mounted so that the shadows cast by the animals fall toward the bottom of the page, i.e., toward the observer. This has been done in accordance with accepted photo interpretation procedure to avoid a pseudoscopic (false stereo) effect. Nevertheless, the reader may find it both interesting and informative to rotate the figure 180 degrees and then note the very close similarity between the shadow of each animal and the corresponding appearance of the animal itself as viewed by a ground observer. Thus these examples provide information as to both the profile and the plan configuration of each type of animal. There is a far better prospect of identifying each animal as to type, breed, sex, age, and vigor if both the vertical and the horizontal views are considered, than if only one of these views is considered. The photo interpreter who realizes this important fact will take pains to interpret both the animal and its shadow whenever possible, as he attempts to make livestock inventories from aerial photographs. Photos were taken from the tower both at mid-day and in the late afternoon to determine the optimum elevation of the sun above the horizon in relation to livestock shadow interpretations.

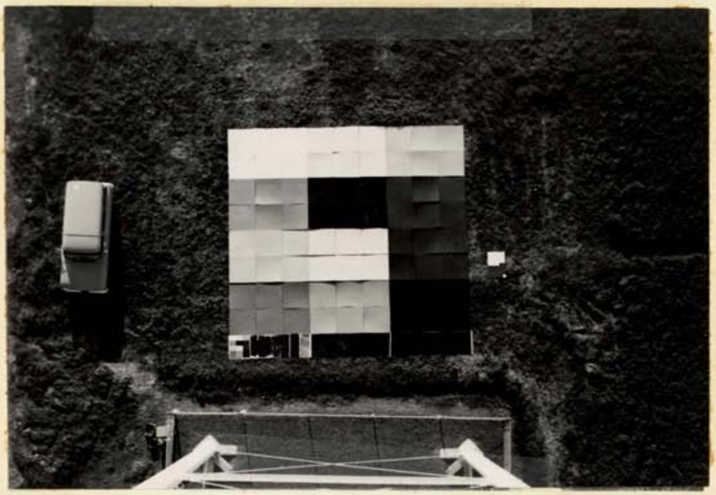
At the same time as the <u>simulated</u> aerial photos of the target array were being obtained from the water tower, a limited number of <u>actual</u> aerial photos

also were being obtained of the same array from a Cessna 180 aircraft. Flight altitudes in feet for the aerial photos were 300, 600, 1200, and 2400, respectively. Film-filter combinations used were panchromatic-minus blue, infrared-89B, Ektachrome-HF 5, and Ekta Aero Infrared film with both a Wratten 12 and an EF 2200 (color correction) filter. The Zeiss aerial camera used had a focal length of 6 inches, a negative size of 9 x 9 inches, and an average resolution over the entire field of approximately 40 lines per millimeter, as compared with only about 20 lines per millimeter for most aerial cameras. The largest scale of photography thus obtained was roughly the same as that obtained from the water tower; hence the simulated and actual aerial photos could be directly compared. When this was done, it became apparent that an aerial photo interpreter can draw valid conclusions from the economical water tower photography (as to the relative merits of various film-filter combinations, and as to the photo interpretability of livestock for example), thus eliminating the need for flying large amounts of costly aerial photography to make these determinations.

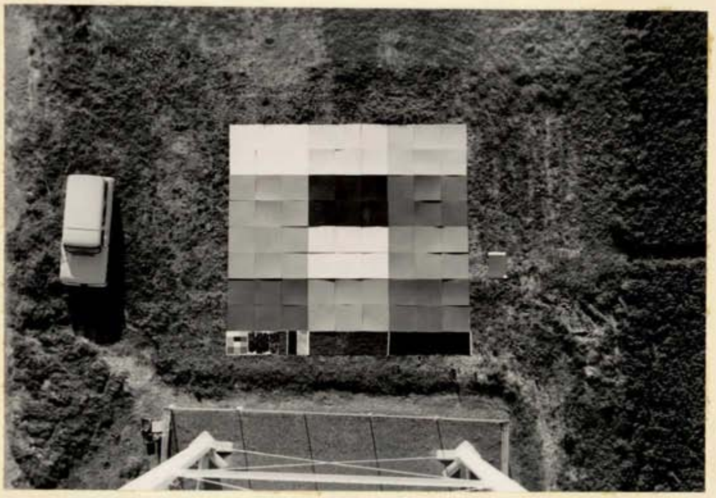
As illustrated by many of the examples appearing in this report, for each film-filter combination two photos were taken simultaneously from the water tower, through the use of two matched Speed Graphic cameras. In order to investigate the effect on interpretability that results from varying the stereoscopic parallax of the animals, the two overlapping photos were taken simultaneously using two photographers stationed a known distance apart on the catwalk of the water tower. The main reason for taking the two photos of each pair simultaneously was to eliminate troublesome stereoscopic effects that otherwise would have been introduced by movements of the animals of the target array during the interval between exposures.

Still another aspect of the livestock inventory problem which could be economically studied from the water tower photography was that of image contrast in relation to image interpretability. Vidya personnel attributed a major part of their difficulty in interpreting operational photography to the fact that too much contrast was present in the photos. In order to further investigate the extent to which tone contrast affects livestock interpretability, some of the Davis water tower photos purposely were underexposed and over-developed (to give minimum contrast) and the remainder were given normal exposure and development in an effort to obtain optimum contrast. Furthermore, both high contrast and low contrast films were included in these tests. It seemed desirable to qualify tone values in this aspect of the study by using objects having known brightness values. This explains the presence of the square panels which appear in all photos taken from the water tower. These are part of a special target array that was constructed from 72 Masonite panels, each 4 feet square, in order to investigate the tone contrast problem more adequately. The panels were painted to various color and brightness values, using paints that provided a stepwise progression of the color scale as recommended by the Colorimetry Laboratory of the National Bureau of Standards. The entire set of panels was placed beneath the Davis water tower on a day subsequent to that in which the livestock of Figure 1 were photographed. The array of panels was photographed with each of the film-filter combinations used in the previously described photography, and at both high and low sun angles. Several of the photographs of this series are shown in Figures 11 and 12.

The water tower tests were followed by tests made with aerial photos of livestock on representative range lands and pasture lands. The examples shown in Figures 13 through 18 are representative of summertime photography

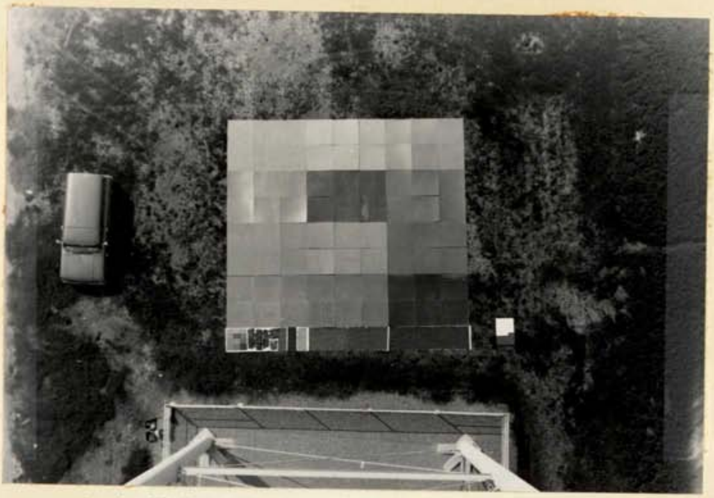


Scale 1/200; Panchromatic Film; Wratten 61 Filter

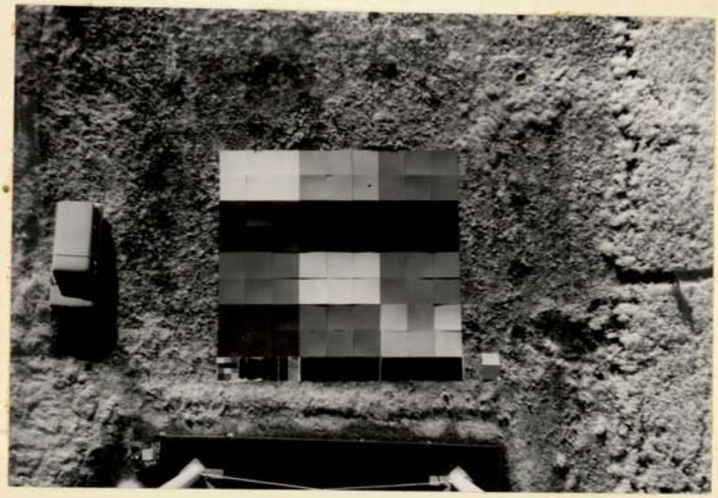


Scale 1/200; Panchromatic Film; Wratten 12 Filter

Figure 11: Image contrast was analyzed by photographing a color panel target array. The 72 Masonite panels, each 4 feet square, were painted to various color and brightness values.



Scale 1/200; Orthochromatic Film; Wratten 18A Filter

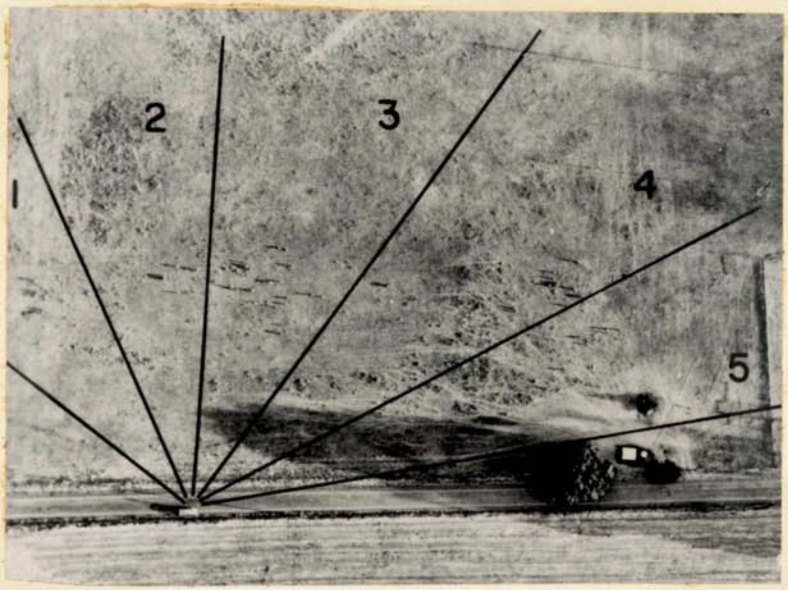


Scale 1/200; Infrared Film; Wratten 89B Filter

Figure 12: Image contrast was analyzed by photographing a color panel target array.

obtained of various range lands and pasture lands in California. In these instances, as in all others, a special effort was made to obtain simultaneous terrestrial photography in order to provide irrefutable "ground truth" against which to check the aerial photo interpretations of livestock. On most of the original aerial photos even the man taking the on-the-ground photos could be discerned on the corresponding aerial photo. He was standing on top of the automobile that appears in the top photo of Figure 13 and from that point he took a panoramic series of five photographs of sheep in the nearby field; he took these photos in rapid succession while the photographic aircraft was overhead, following the prescribed flight line. Two of the five photos in the series are shown beneath the corresponding aerial photo. Although an animal-by-animal tie-in can be made between the aerial photo and corresponding ground photos, careful study shows that despite the precautions described above, a few of the animals are not in identical positions on the aerial and terrestrial photos; this is explained by the fact that the herd is practically never in a static state.

In later experiments, two-way radio communication between the aerial photographer and ground photographer was maintained so that the man on the ground would know exactly when to take a photo that would tie perfectly to a corresponding aerial photo. Lest this degree of refinement seem totally unnecessary in research of this type, a specific instance will be cited: During a period of approximately 15 minutes, four photographic flight lines were made covering the two fields shown in the top photo of Figure 14. On each flight line, the photo interpreters were able to detect virtually every animal. Yet to their amazement, they obtained progressively higher counts, with each pass, for the large field (the one to the right of the freeway) and they obtained progressively lower counts, with each pass, for the small

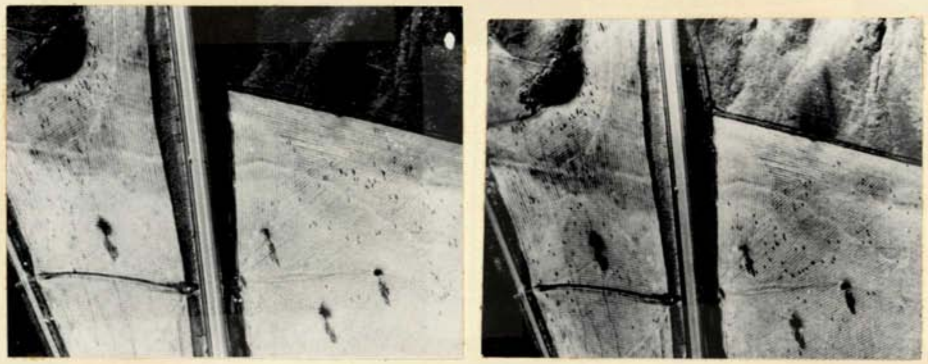



Scale 1/2,000; Panchromatic Film; Wratten 12 Filter
Total number animals present in the 5 sectors = 67

Number of sheep on first sector as seen from point "A" = 7

Number of sheep in third sector as seen from point "A" = 18

Figure 13: Simultaneous ground shots were taken at the instant of aerial photography by a ground photographer on top of automobile at point "A".



Scale 1/6,000; Panchromatic Film; Wratten 12 Filter
Only four minutes elapsed betweed these two exposures; however a photo interpreter could not get a consistent animal count for these two fields.

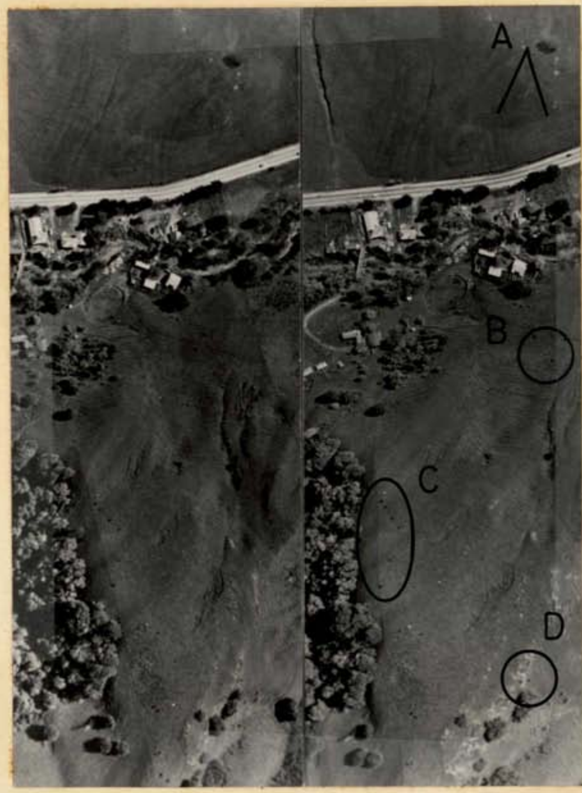
Ground shot showing tunnel connecting the two fields.

Figure 14: The need for accurate "ground truth" is illustrated by these photos. See text for explanation.

field (the one to the left of the freeway). In one instance the count in each field changed by approximately 20 animals when counts were made on photos taken only 4 minutes apart. Without careful on-the-ground checking at the instance of photography this discrepancy would no doubt have been attributed to inability to detect animals consistently. Consequently an unduly pessimistic conclusion would have been drawn as to the feasibility of making an inventory of livestock in these two fields from an interpretation of 1/6000 scale aerial photos. Actually the explanation for virtually all of this discrepancy is apparent when attention is drawn to the underpass beneath the freeway by means of which the livestock can migrate freely from one of the fields to the other. If only the combined total of the animals present in the two fields was being sought, puzzling discrepancies still would have been found. On one of the four passes, for example, 10 to 15 animals were inside the tunnel at the instant of photography and thus did not appear in either of the two fields. Figure 15C illustrates the photo-interpretability of livestock in irrigated pastures.

Figures 15 and 16 illustrate the usefulness of a 300-millimeter telephoto lens in acquiring accurate "ground truth." With this capability, the ground photographer can situate himself in a position on a hilltop or ridge so that the airplane is easily seen, and a wide variety of livestock can be photographed as the plane passes over.

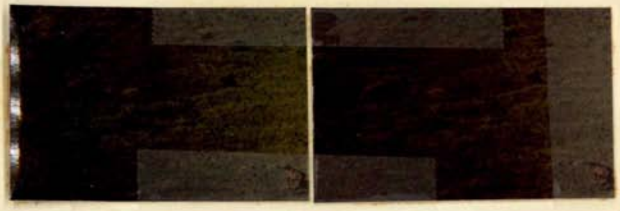
Objects that might be confused with livestock on aerial photos are shown in Figures 17 and 18. The systematic distribution of hay bales and the irregular shape of shadows cast by rock outcropping, plus a lack of subject movement between exposures would allow the photo interpreter to avoid misinterpreting these features as livestock.




Scale 1/4,000; Panchromatic Film; Wratten 12 Filter
Total animals present in encircled areas:

at point "B" = 3 horses
at point "C" = 7 cows
at point "D" = 1 cow

Figure 15: Cattle and horses on fenced rangeland; midwinter seasonal state. Ground shots taken from point "A" at the instant of photography are shown in Figure 16.

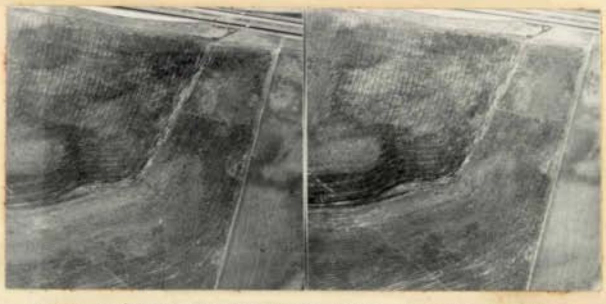


Area circled at point "B"

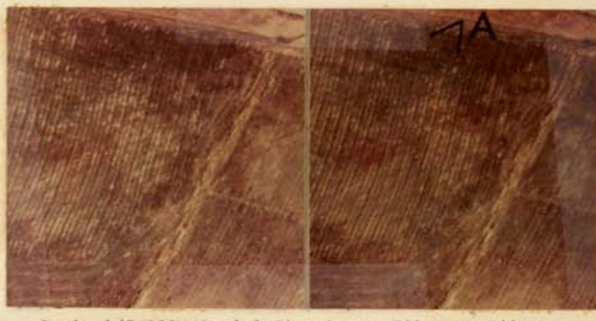
Area circled at point "C"

Area circled at point "D"

Figure 16: Stereo ground shots taken from point "A" of the aerial photos in Figure 15. The ground photographer used a 300 mm telephoto lens.



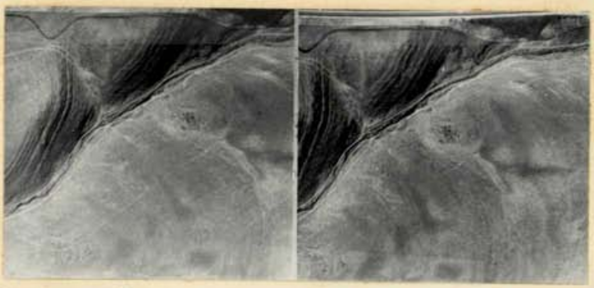
Scale 1/6,000; Panchromatic Film; Wratten 12 Filter




Scale 1/5,000; Aerial Ektachrome Film; No Filter

Ground shot taken at the instant of aerial photography.
Total number of animals present = 0.

Figure 17: Hay bales can easily be confused with animals on aerial photography. Note the relatively uniform spacing of the hay bales and the regular size and shape.



Scale 1/6,000; Panchromatic Film; Wratten 12 Filter


Scale 1/5,000; Aerial Ektachrome Film; No Filter

Stereo ground shot taken at instant of aerial photography. Total number of animals present = 0

Figure 18: Rock outcropping can easily be confused with animals on aerial photography. Note the highly irregular size and shape of the rocks.

Based on work performed in California to date, the following conclusions are indicated relative to the feasibility of inventorying livestock by means of aerial photography: (1) In fields such as those shown in Figure 15, which are considered representative of many of the areas in which livestock inventories are desired, errors of greater than five per cent in total livestock counts are rarely made by the photo interpreter. (2) In areas having a denser vegatation cover than is shown in Figure 15, the accuracy falls off very rapidly to a point where less than ten per cent of the total animals present in a field can be detected on aerial photos. (3) Many errors in the inventory of livestock on small scale photography can be avoided if the photo interpreter first studies illustrations from <u>large scale</u> photography. (4) Photos taken of livestock at low sun angle usually are preferable because of greater shadow detail and the greater tendency for these animals to be in the open during the cool of the day. (5) For mapping range conditions the best film-filter combination of those tested is aerial Ektachrome film with a haze filter; panchromatic film with a light red (25A) filter is next best. Under California conditions, the optimum time for aerial photography of range lands is in the late spring. Livestock tend to be most interpretable at that time of year also because: (a) the weather is cool enough so that cattle are not so likely to seek shade; (b) most of the grass is green and contrasts better with sheep and other light-toned animals; (c) sheep have only recently been shorn and hence are very light in tone; (d) trees may not be in full leaf and hence may not obscure livestock as much as in mid-summer.

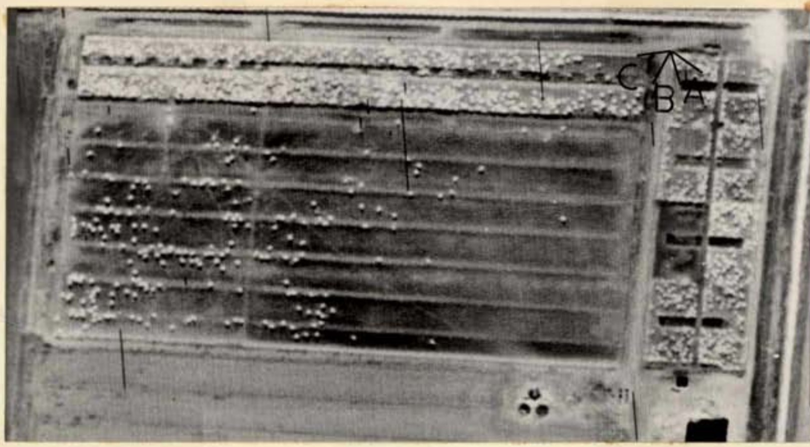
Although conventional photography is useful for the inventory of livestock, another type of imagery, thermal infrared, is also available. For this phase of the study portions of the Imperial Valley of California were

flown in October, 1963, with a Reconofax-4 sensor operating in the thermal infrared region of the electromagnetic spectrum (8-14 microns). An agricultural activity shown on the obtained imagery is a cattle feedlot. Previous mention of this cattle feedlot was made in Part I of this report. At the time the imagery was taken, it contained approximately 2000 cattle. While many varieties of cattle were present, it is impossible on the imagery to distinguish between them.

An enlargement of the feedlot imagery and two panchromatic ground shots are shown in Figure 19. The dark rectangular objects seen on the right side of the enlargement are straw-covered canopies, installed to provide shade for the cattle (see photos taken at Point A). There is one canopy for each of the eight pens; no cattle were in one of the pens. A path, shown dividing the area and perpendicular to the canopies, provides access to the pens. A longer, more mottled feature, appearing to separate the cattle into two long, densely populated pens, is a canopy similar to the others. However, straw is absent from some areas of the canopy permitting cattle under it to be seen from above. The remaining and largest portion of the feedlot formed a corral. However, since the time the imagery was taken, this portion has also been segmented into units. (See photos taken from Point B.)

In addition, the field at the lower edge of the enlargement grows alfalfa. The three dark, round features near the edge of this field are tall silos containing feed for the cattle. Lastly, the black, box-shaped features in the area are dwellings; the large, black square is a barn.

Thermal Infrared Imagery of Cattle Feedlot
Imperial Valley, California
(Unclassified imagery taken with a Reconofax-4 sensor, courtesy of HRB-Singer, Inc.)





Panchromatic Ground Shot taken of feedlot from Point A

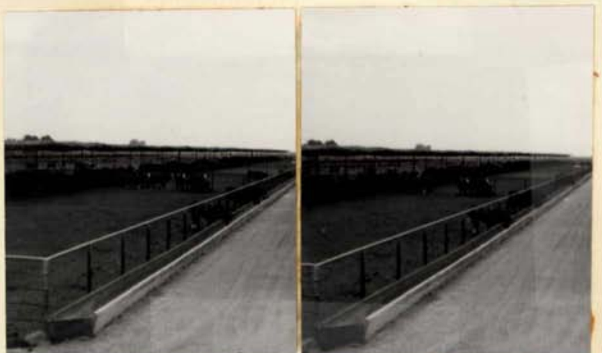

Ektachrome ground shot taken of feedlot from Point A

Figure 19

Stereo Ground Shots of Cattle Feedlot
Imperial Valley, California

Panchromatic Ground Shot taken of feedlot from Point B, shown on the thermal infrared enlargement.

Ektachrome Ground Shot taken of feedlot from Point B, shown on the thermal infrared enlargement.



Panchromatic Ground Shot taken of feedlot from Point C, shown on the thermal infrared enlargement

Ektachrome Ground Shot taken of feedlot from Point C shown on the thermal infrared enlargement

Figure 20

## PHOTO INTERPRETATION KEY FOR LIVESTOCK TYPES AND BREEDS

A photo interpretation key is reference material designed to facilitate rapid and accurate identification and determination of the significance of objects or conditions from the analysis of their photo images. Without knowledge or familiarity of a given area supplemented with accurate "ground truth" a photo interpreter can only draw on past experience when identifying objects on aerial photos. However, if some type of reference material or guide is available, depicting a means of identifying the same area or a similar area, accurate interpretation can be made regardless of photo interpretation experience or familiarity with the area.

The most useful key for the recognition of animal types and breeds consists of three parts: (1) a word description of each animal as imaged on aerial photos that utilize pre-determined optimum photographic specifications, (2) aerial photo stereograms and schematic drawings that illustrate each animal, (3) a word description of animal size, tone, and morphological differences arranged in a dichotomous fashion so that each animal can be easily eliminated upon recognition of its photographic features.

The following set of keys describing livestock types and breeds are based on large scale photographs taken from the catwalk of the Davis water tower. Not all types and breeds of animals studied were present in the Davis target array and therefore are not included in these keys.

# A SELECTIVE PHOTO INTERPRETATION KEY FOR <u>LIVESTOCK</u> USING AERIAL PHOTOGRAPHY

## FEASIBILITY RATINGS FOR THE PHOTO INTERPRETATION OF LIVESTOCK

On the succeeding two pages are tables indicating the feasibility of detecting and recognizing various types and breeds of livestock on aerial photographs flown with four different film-filter combinations, at each of four photographic scales, and at each of the two major seasonal states encountered in California. The symbols appearing in the various squares of these tables have the meanings indicated in the legends for the respective tables. The ratings represent the concensus of ten photo interpreters who were actively engaged in this research, each of whom independently assigned feasibility ratings for each square of the tables. The ratings are based on a maximum of 4-power magnification.

In arriving at these ratings each photo interpreter had access to nearly two hundred stereoscopic examples of the types appearing herein, for each of which accurate ground truth, (including stereo ground shots) had been obtained either at the instant of aerial photography, or very shortly thereafter. Even with this large number of examples, however, it often was necessary to extrapolate from aerial photographic examples that had been flown to specifications that were similar to, but not identical with those called for in some particular square of the tables. Nevertheless, the critical threshold range for photographic scales (the 1/6,000 to 1/8,000 range) was well covered by aerial photographic examples and accompanying ground photos.

FEASIBILITY OF IDENTIFYING CALIFORNIA <u>LIVESTOCK TYPES</u> ON AERIAL PHOTOGRAPHY

Winter and Spring Seasonal State ( green background )

| Animal Type | Photo Scale and Film - Filter | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1/2,000 | | | | 1/4,000 | | | | 1/6,000 | | | | 1/8,000 | | | | 1/12,000 | | | |
| | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD |
| Mature Cattle | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | ++ | ++ | + | + | ++ | ++ | - | - | - | - |
| Mature Horses | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | ++ | ++ | + | + | ++ | + | - | - | - | - |
| Mature Sheep | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | ++ | ++ | + | + | + | + | - | - | - | - |
| Mature Goats | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | + | + | - | - | + | - | - | - | - | - |
| Mature Pigs | ++ | ++ | ++ | ++ | ++ | + | ++ | + | + | + | + | + | - | - | + | - | -- | -- | -- | -- |
| Calves | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | + | + | + | - | + | + | - | - | - | - |
| Colts | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | + | + | + | - | + | + | - | - | - | - |
| Lambs | ++ | ++ | ++ | ++ | ++ | + | ++ | ++ | + | + | + | + | - | - | + | + | -- | -- | -- | -- |

Summer and Fall Seasonal State ( brown background )

| Animal Type | Photo Scale and Film - Filter | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1/2,000 | | | | 1/4,000 | | | | 1/6,000 | | | | 1/8,000 | | | | 1/12,000 | | | |
| | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD |
| Mature Cattle | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | ++ | ++ | + | + | ++ | + | - | - | - | - |
| Mature Horses | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | ++ | ++ | + | + | + | + | - | - | - | - |
| Mature Sheep | ++ | ++ | ++ | ++ | ++ | + | ++ | ++ | + | + | ++ | + | + | + | + | + | - | - | - | - |
| Mature Goats | ++ | ++ | ++ | ++ | + | + | ++ | ++ | + | + | + | + | - | - | - | - | -- | -- | - | - |
| Mature Pigs | + | + | ++ | ++ | + | - | + | + | - | - | + | - | - | -- | - | - | -- | -- | -- | -- |
| Calves | ++ | ++ | ++ | ++ | + | + | ++ | ++ | + | + | + | + | - | - | + | + | - | - | - | - |
| Colts | ++ | ++ | ++ | ++ | + | + | ++ | ++ | + | + | + | + | - | - | + | + | - | - | - | - |
| Lambs | ++ | ++ | ++ | ++ | + | + | ++ | + | - | - | + | - | - | -- | - | - | -- | -- | -- | -- |

Legend:

++ consistently detectable as livestock and usually identifiable as to type.

\+ usually detectable as livestock, but only occasionally identifiable as to type.

\- only occasionally detectable as livestock and rarely identifiable as to type.

-- consistently neither detectable as livestock, nor identifiable as to type.

FEASIBILITY OF IDENTIFYING CALIFORNIA CATTLE BREEDS ON AERIAL PHOTOGRAPHY

Winter and Spring Seasonal State ( green background )

| Cattle Breed | Photo Scale and Film - Filter | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1/2,000 | | | | 1/4,000 | | | | 1/6,000 | | | | 1/8,000 | | | | 1/12,000 | | | |
| | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD |
| Jersey | ++ | ++ | ++ | ++ | ++ | + | ++ | ++ | + | + | ++ | ++ | - | - | + | + | -- | -- | - | -- |
| Holstein | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | ++ | + | - | - | - | - |
| Guernsey | ++ | ++ | ++ | ++ | ++ | + | ++ | ++ | + | + | ++ | ++ | - | - | + | + | -- | -- | - | -- |
| Angus | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | ++ | + | - | - | - | - |
| Hereford | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | ++ | + | - | - | - | - |
| Hereford-Angus | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | ++ | ++ | + | - | + | + | -- | -- | - | -- |

Summer and Fall Seasonal State ( brown background )

| Cattle Breed | Photo Scale and Film - Filter | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1/2,000 | | | | 1/4,000 | | | | 1/6,000 | | | | 1/8,000 | | | | 1/12,000 | | | |
| | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD | PMB | IR89 | EKTA | CD |
| Jersey | ++ | ++ | ++ | ++ | + | + | ++ | + | + | - | + | + | - | - | + | + | -- | -- | - | -- |
| Holstein | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | ++ | + | + | + | ++ | + | - | - | - | - |
| Guernsey | ++ | ++ | ++ | ++ | + | + | ++ | + | + | - | + | + | - | - | + | + | -- | -- | - | -- |
| Angus | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | + | + | + | + | ++ | + | - | - | - | - |
| Hereford | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | + | + | - | - | + | + | - | - | - | - |
| Hereford-Angus | ++ | ++ | ++ | ++ | + | + | ++ | + | + | - | + | + | - | - | ++ | + | -- | -- | - | -- |

Legend:

| | | | |
|---|---|---|---|
| ++ | usually identifiable as to breed | - | rarely identifiable as to breed |
| + | occasionally identifiable as to breed | -- | not identifiable as to breed |

## SUMMARY OF FINDINGS RELATIVE TO THE AERIAL PHOTO INTERPRETATION OF LIVESTOCK

Reference to the tables appearing on the two preceding pages can be very helpful when one seeks to draw conclusions as to the optimum aerial photographic specifications for livestock inventories. Among the conclusions that can be inferred from a study of these tables and of the photographs from which they were derived are the following:

1. Aerial photography flown at times of the year when the grass is green (winter and spring seasonal state) is somewhat more interpretable than that flown when the grass is brown (summer and fall seasonal state). In most of California the transition from green to brown occurs in the month of May and from brown to green in the month of November.

2. Aerial color photography (especially aerial ektachrome) is decidedly superior to black-and-white (either panchromatic or infrared) for differentiating breeds of cattle. Color photography is little if any better than black-and-white for the making of mere livestock counts during the summer and fall seasonal state when the background is brown. However, color photography seems to be significantly better for this purpose during the winter and spring seasonal state when the background is green.

3. Even with the relatively high resolution obtained with the Zeiss camera, it was found that at photographic scales of 1/8,000 and smaller, the ease and accuracy with which livestock can be inventoried diminishes rapidly. As photographic scale is increased from 1/6,000 to 1/2,000 there is a progressive and quite significant increase in the accuracy with which livestock inventories can be made. However, it must be kept in mind that a doubling of the

photographic scale almost quadruples the cost per unit area photographed. Consequently, there is a significant "trade-off" between total area that can be photographed for a given sum, and accuracy of interpretation per unit area. In view of this trade-off the tables suggest that the optimum photographic scale is about 1/6,000 for most livestock inventories when using the Zeiss camera. A study of prints made from panchromatic aerial photography flown with a HyAc camera (at the same time and of the same area as was being covered by the Zeiss camera) indicates that livestock inventories could also be made on this photography at a scale of 1/6,000.

4. An examination of photographs taken with a very large number of black-and-white film-filter combinations (especially those taken from the Davis water tower, of the same target array, at nearly the same time, and from precisely the same camera stations) suggests that ordinarily panchromatic photography is preferable to infrared and that the conventional Wratten 12 (minus blue) filter is either superior to, or as good as any other filter.

5. The greater cost of color photography as compared with black-and-white photography suggests that ordinarily the latter is preferable in making an inventory where the emphasis is on determining the number of livestock by type. The black-and-white photography permits a larger area to be sampled at the same cost. However, additional information can be obtained concerning cattle breeds by the use of aerial ektachrome photography.

6. Stereoscopic coverage (60% forward overlap) usually is necessary to make accurate livestock counts. Image movement between stereo pairs is an important means of detecting livestock, which are seldom in a static state (as are rocks and bushes with which they might otherwise be confused). In addition, stereo coverage gives two spatial vantage points of the area to be interpreted

and thus minimizes the troublesome problem of fall-off (poorer image quality for areas imaged near the edge of any given photograph) in making livestock inventories. The amount of stereo parallax provided on Zeiss camera photography flown to optimum scale and overlap specifications appears to be ideal for exploiting the third dimension when interpreting livestock that have remained essentially stationary during the interval between successive exposures.

In summary, it has been concluded from this study that the optimum specifications for aerial photography that is to be used in making livestock inventories with a Zeiss precision aerial camera are: Panchromatic film, minus-blue filter, scale 1/6,000, 60% forward overlap. Ideally the photography should be taken in the early morning during the winter and spring seasonal state, when the grass forms a green background against which the images of livestock contrast well. Additional non-stereoscopic color photography (e.g. with 10% forward overlap or slightly less) at a scale of 1/8,000 or larger, would be very helpful in the identification of cattle breeds.

It also has been concluded from this study that the inventory of livestock from aerial photographs flown to the above specifications, and supplemented with only a limited amount of simultaneous ground checking, is feasible in areas of California having less than about 20 to 30% cover of woody vegetation, provided that the photography is taken at a time when the animals are not likely to be "shaded up" beneath trees. During the brown grass (summer and fall) seasonal state, the cattle are far less likely to be shaded up during the first two hours after sunrise, and the last two hours before sunset, than during the middle part of the day.

## A DICHOTOMOUS PHOTO INTERPRETATION KEY FOR ANIMAL TYPES ON LARGE SCALE PANCHROMATIC PHOTOGRAPHY

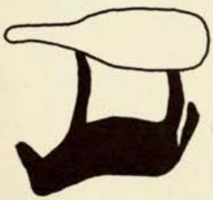
1. Body measures longer than 6 feet .............................. 2
1. Body measures shorter than 6 feet ............................. 5
    2. Neck measures longer than 2 feet .......................... 3
    2. Neck measures approximately 1 foot long ................... 4
3. Legs are long and thin; ears are small........................ Horse
3. Legs are long and thin; ears are long and protrude .......... Jackass
    4. Neck is thin; body is rounded; horns are small or missing.......... Cow or Steer
    4. Neck is thick; body is "blocky"; horns when present are generally large ........................................ Bull
5. Generally not found in a small enclosure ...................... 6
5. Generally found in a small enclosure that is sometimes wet and muddy ................. Pig
    6. Neck is short, legs are short ............................. 7
    6. Neck is long, legs are long ............................... Colt
7. Body is lean and "bony"; not always light in tone .............. 8
7. Body is "tear-drop" shaped; always light in tone ............. Sheep
    8. Shoulders, back and rump are thin; abdomen is broad ....... Goat
    8. Abdomen is slightly broader than shoulders, back and rump...Calf

## A. Horse

Scale: 1 inch = 5 feet

**Aerial Description**: The mature horse has a body length of 7-9 feet. The neck is very long and thin. The shoulders and back are nearly the same width while the rump measures slightly wider. The shadow indicates long spindly legs, a long neck, a full tail and a slender body.

**Shadow Chracteristics**:



Perpendicular to sun

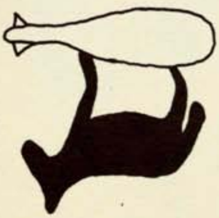
Parallel to sun

B. Jackass

Scale: 1 inch = 5 feet

Aerial Description: The mature Jackass has a body length of 7-9 feet. The neck is long and thin. The shoulders are slightly narrower than the back and rump. Very long protruding ears are distinctly visible in the shadow. The shadow also indicates long spindly legs, a long neck, a full tail and a slender body.

Shadow Characteristics:



perpendicular to sun

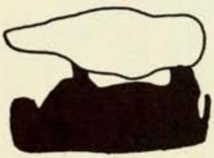
parallel to sun

C. Cow or Steer

Scale: 1 inch = 5 feet

Aerial Description: The mature cow or steer has a body length of 6 to 8 feet. The neck is short and thin. The abdomen and back appear slightly broader than the shoulders. The body has a rounded appearance. The shadow indicates a heavy rounded abdomen, short stocky legs and a thin tail.

Shadow Characteristics:



perpendicular to sun

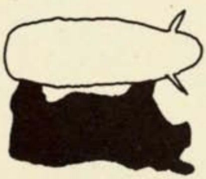
parallel to sun

## D. Bull

Scale: 1 inch = 5 feet

Aerial Description: The mature bull has a body length of 7 to 9 feet. The neck is short and very thick and the shoulders and back are broad. The body has a very muscular and "blocky" appearance. Horns are sometimes visible. The shadow indicates a heavy body, short stocky legs, protruding horns, a thin tail, and sometimes the characteristic sex organ.

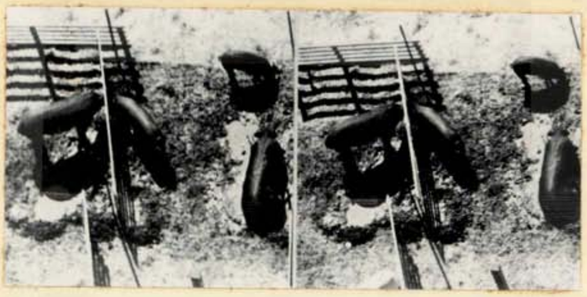
Shadow Characteristics:



perpendicular to sun

parallel to sun

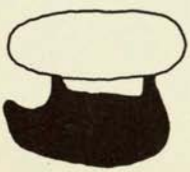
E. Pig



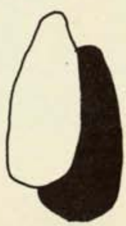
Scale: 1 inch = 5 feet

Aerial Description: The mature pig has a body length of 4 to 6 feet. It is dark or light in tone and has a glossy appearance. It is generally found in a small enclosure that is sometimes wet and muddy. The body is "sausage" shaped with a small head and a very short thick neck. The shadow indicates short thick legs and a bulky body.

Shadow Characteristics

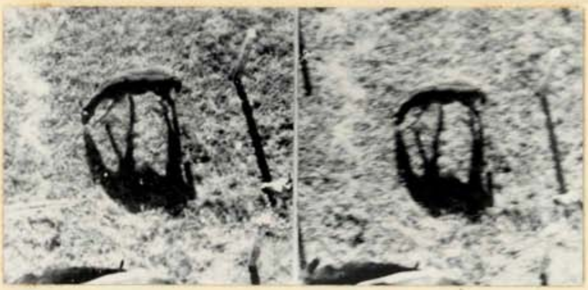


perpendicular to sun



parallel to sun

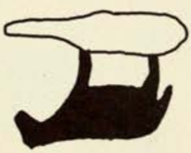
F. Colt



Scale: 1 inch = 5 feet

Aerial Description: The colt has a body length of 4 to 6 feet. The neck is very long and thin. The shoulders, back and rump are nearly the same width. The body is long and slender and a bit more "bony" than the mature horse. The shadow indicates long spindly legs, a long neck, a full tail and a slender body.

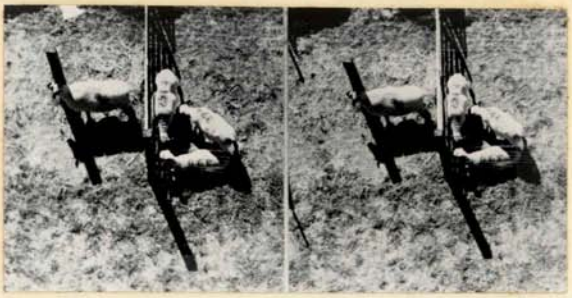
Shadow Characteristics:



perpendicular to sun

parallel to sun

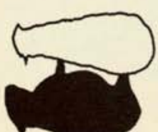
## G. Sheep



Scale: 1 inch = 5 feet

Aerial Description: The mature sheep has a body length of 3 to 4 feet. It is always light in tone but sometimes has a dark toned face. The body is distinctly "tear-drop" shaped with the back being the widest point. The head is small with short protruding ears. The neck is short and is visible only on shorn sheep. Unshorn sheep have a much fuller appearance. The shadow indicates short spindly legs and a bulky body.

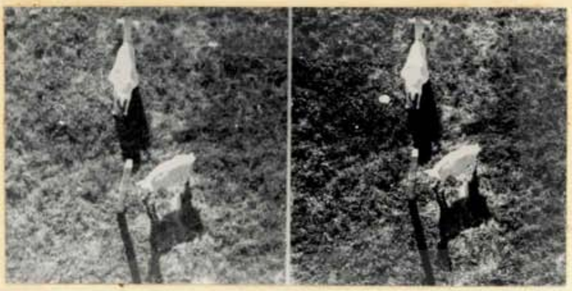
Shadow Characteristics:



Perpendicular to sun

Parallel to sun

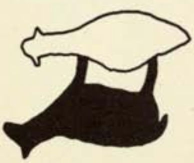
## H. Goat



Scale: 1 inch = 5 feet

**Aerial Description**: The mature goat has a body length of 3 to 4 feet. It can be grey, white, or black; therefore, tone will not provide a reliable guide for identification. The shoulders and rump are very narrow and the abdomen is wide. The neck is of medium length, the head is small and the short ears protrude. The shadow indicates short spindly lengs, a short tail, and a very lean body.

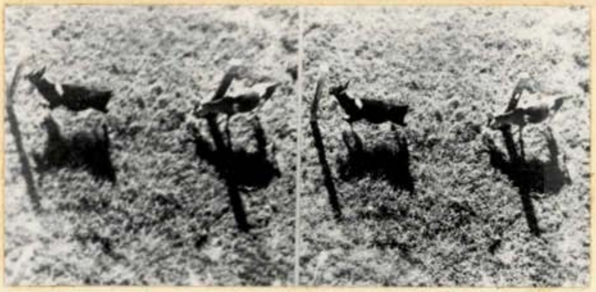
**Shadow Characteristics**:



perpendicular to sun

parallel to sun

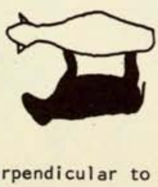
## I. Calf



Scale: 1 inch = 5 feet

**Aerial Description**: The calf has a body length of 3 to 5 feet. The neck is short and thin. The shoulders, back, and rump appear lean and "bony" and the abdomen is slightly wider. The shadow indicates short spindly legs, a thin tail and a slender body.

**Shadow Characteristics**:



perpendicular to sun

parallel to sun

## A DICHOTOMOUS PHOTO INTERPRETATION KEY FOR ANIMAL BREEDS ON LARGE SCALE PANCHROMATIC PHOTOGRAPHY

### A. Cattle

1. Animal is predominantly light toned ........................ 2
1. Animal is predominantly dark toned ......................... 4
    2. Large dark toned patches visible ....................... 3
    2. No pattern is visible; 100% light toned ............. Jersey
3. Large very dark patches visible ...................... Holstein
3. Large light grey patches visible ..................... Guernsey
    4. Light toned markings visible ........................... 5
    4. No markings; 100% very dark toned .................... Angus
5. A single light toned shoulder patch and/or white face is visible ................. 6
5. Large light toned patches visible .................... Holstein
    6. White (light toned) face with no shoulder patch ......... 7
    6. White (light toned) face with a shoulder patch .......... 8
7. Very dark toned ..................................... Hereford-Angus
7. Dark toned ............................................. Hereford
    8. Shoulder patch is small ............................. Hereford
    8. Shoulder patch extends to rump ................ Hereford-Shorthorn

### B. Horses

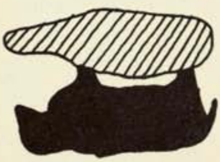
1. Medium sized body; narrow back ...................... Quarterhorse
1. Large sized body; wide back ......................... Thoroughbred

A. Cattle 1. Jersey

Scale: 1 inch = 5 feet

Aerial Description: The Jersey is a solid tan color; therefore, it appears 100% light toned on panchromatic photography.

Shadow Characteristics:



perpendicular to sun

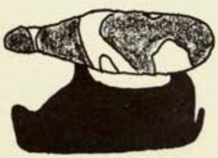
parallel to sun

## 2. Holstein

Scale: 1 inch = 5 feet

Aerial Description: The Holstein is easily recognized by a distinctive black and white pattern. The predominant tone may be either black (very dark toned) or white (very light toned) while the complement tone will generally appear in very large patches.

Shadow Characteristics:



perpendicular to sun

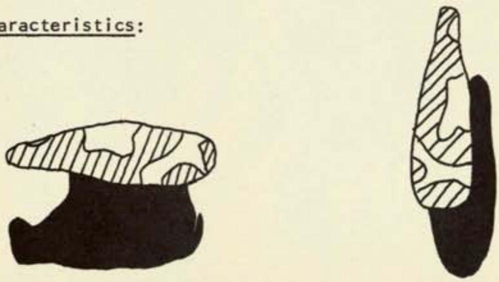
parallel to sun

3. Guernsey

Scale: 1 inch = 5 feet

Aerial Description: The Guernsey is easily recognized by a distinctive tan and white pattern. The predominant tone may be either tan (light toned or white (very light toned) while the complement tone will appear in very large patches.

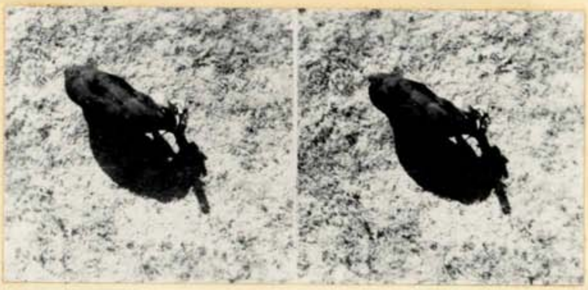
Shadow Characteristics:



perpendicular to sun

parallel to sun

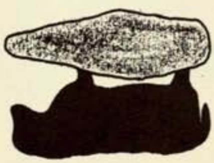
## 4. Angus



Scale: 1 inch = 5 feet

Aerial Description: The Angus is a solid jet black color; therefore, it appears 100% very dark toned on panchromatic photography.

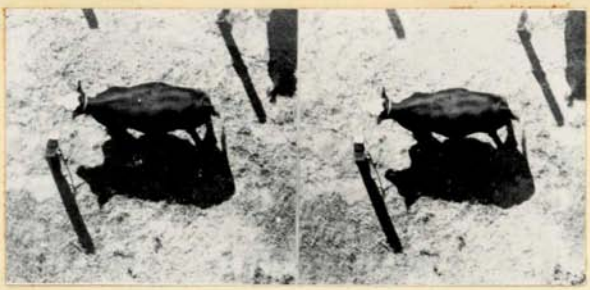
Shadow Characteristics:



perpendicular to sun

parallel to sun

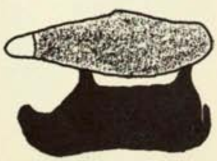
## 5. Hereford-Angus



Scale: 1 inch = 5 feet

Aerial Description: The Hereford-Angus cross is predominantly jet black in color with a white face. It appears very dark in tone with a very light toned face on panchromatic photography.

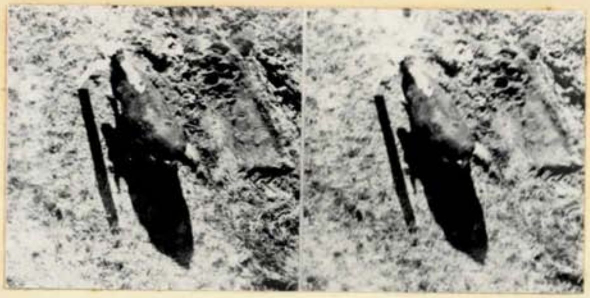
Shadow Characteristics:



perpendicular to sun

parallel to sun

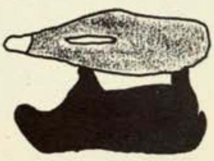
## 6. Hereford



Scale: 1 inch = 5 feet

Aerial Description: The Hereford is predominantly dark toned due to a deep sorrel color. The face is white; therefore appears very light in tone. Sometimes but not always a small white (light toned) patch appears on the shoulders.

Shadow Characteristics:



perpendicular to sun

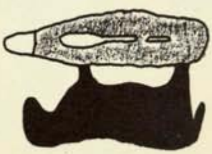
parallel to sun

7. Hereford-Shorthorn

Scale: 1 inch = 5 feet

Aerial Description: The Hereford-Shorthorn cross is predominantly dark in tone due to a deep sorrel color. The face and head are white; therefore appear very light in tone. A wide white (light toned) strip appears along the shoulders tapering to the rump. White is sometimes visible along the abdomen and rib cage.

Shadow Characteristics:



perpendicular to sun

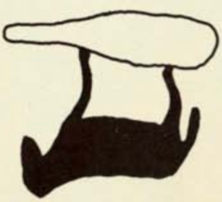
parallel to sun

B. Horses 1. Quarterhorse

Scale: 1 inch = 5 feet

Aerial Description: The mature Quarterhorse can appear grey, white, or black; therefore, tone will not provide a reliable guide for identification. It is differentiated from the thoroughbred by its narrower back and generally smaller size.

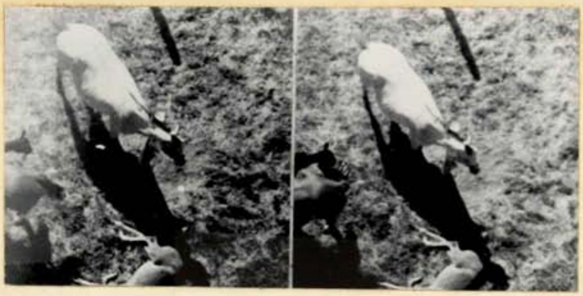
Shadow Characteristics:



perpendicular to sun

parallel to sun

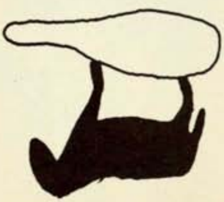
2. Thoroughbred



Scale: 1 inch = 5 feet

**Aerial Description**: The mature Thoroughbred can be grey, white or black; therefore, tone will not provide a reliable guide for identification. It is differentiated from the Quarterhorse by its broad back and generally larger size.

**Shadow Characteristics**:



perpendicular to sun

parallel to sun

# VOLUME II

## PART II

### SOIL AND WATER

## THE USEFULNESS OF AERIAL PHOTOGRAPHY FOR THE ANALYSIS OF THE SOIL AND WATER RESOURCES

An adequate inventory of the soil and water resources of and area is prerequisite to the development of a proper agricultural program for the area. Full utilization of fields containing soils of suitable quality and the efficient allocation of the water to such fields are becoming increasingly important considerations to the agriculturist. Emphasis in this section of the Report is placed on the feasibility of detecting differences in soil moisture and soil fertility factors.

Aerial photographs are used in hydrology to study surface conditions that influence or control the phases of the hydrologic cycle. Measuring the quantity of precipitation falling on an area is made easier if aerial photographs are used. The loss of precipitation by interception and evapotranspiration is related to the surface conditions, which are determined by aerial photo interpretation. Precipitation desposition as runoff, storage, or seepage can be estimated in part from interpretation of physical conditions of the area made on aerial photographs. The yeild of water from an area can be estimated from assumptions and deductions derived through a study of the patterns of drainage systems, the size and shape of stream channels, and the presence of springs and seepage areas as they are interpreted from the photographs. The depth of ground water in various parts of the watershed can often be estimated from vegetation types and patterns of land forms interpreted from the aerial photographs. The processes of erosion in the watershed can be observed, the source of deposited material can be found, the movement of sediment can be traced and alluvial

deposits can be identified by interpretation of aerial photographs.

The choice of management practices to be used in a watershed should be based on information about the hydrologic cycle of that watershed. This information is usually most useful in the form of maps or charts that show the distribution of factors affecting water in the area. The soil and vegetation types present in the watershed can be identified and delineated on aerial photographs and transferred to a base map. The distribution and areal extent of each type, when known, can be used as the basis for assigning priorities of action in various aspects of watershed management. Maps of potential water supply for agricultural, urban, and industrial development can be made byphoto interpretation. The geologic structure and physical and topographic conditions of the beds of rivers and streams can be photo interpreted to provide basic information for constructing dams to impound water for domestic, agricultural and commercial purposes and to provide electric power. Erosion control work can be expedited by studying aerial photographs that show potential erosion where it occurs in the watershed.

Soils can be interpreted in aerial photographs by study of the patterns created by the nature of the parent rock, the mode of deposition, and the climatic, biotic, and physiographic environment. To the experienced observer, many of these patterns are distinctive. They can be correctly interpreted in the light of three important principles:

(a) Similar soils appear in similar patterns. Any two soil materials derived for the same parent rock, deposited in the same way, and occupying similar topographic positions under the same

environmental conditions have similar properties and exhibit similar patterns.

(b) Dissimilar soils appear in dissimilar patterns.

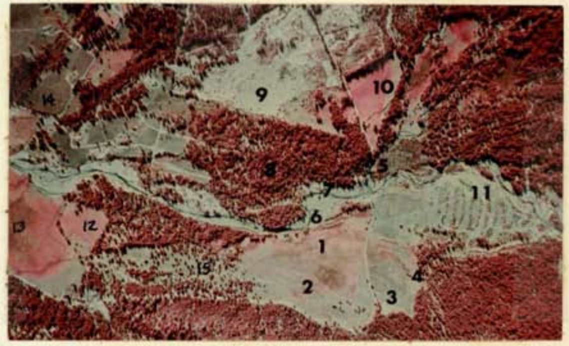
(c) Once photographic image characteristics have been correlated with soil properties observed in field and laboratory, the sequence of events which formed a particular soil can often be reconstructed by means of photo interpretation, and many important properties of similar soils can be inferred.

Figures 1 through 4 explain the various ways that aerial photography can be utilized for the inventory and anlysis of these resources. Figure 1 is especially useful, showing the various features on six different film-filter combinations. The thermal infrared imagery (Figure le) is particularily useful for detecting moisture conditions and drainage patterns.

a) Panchromatic minus-blue filter

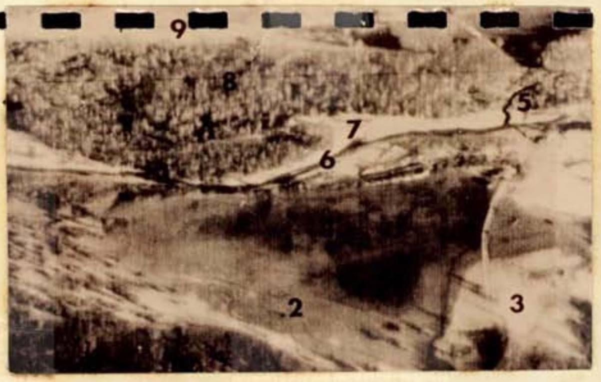
b) Aerographic Infrared Wratten 89B filter


c) Ektachrome

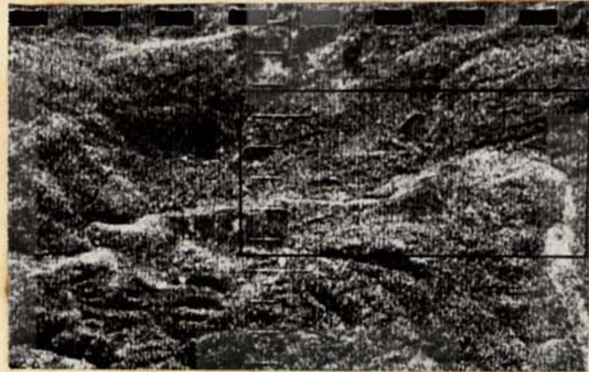



d) Ekta-Aero Infrared Wratten 12 filter

Figure 1. High altitude aerial photographs (scale 1/10,000) of pasture and rangeland in Meadow Valley, California; Bucks Lake test site, taken September 26, 1965. Note the ease of detecting the pastures (10) and other fields (12) on photos (b) and (d), which at this time of year are still green and vigorous due to periodic irrigation or high water table. Poorly drained sites (1 and 14) support a distinct community of rushes and sedges and are best identified by their peculiar color on photos (c) and (d). Well-drained or gravelly soils (3) lack sufficient moisture to maintain the vigor of annual grasses, forbs or perennials which dry early in the season. Note that ponderosa pine (*Pinus ponderosa*) has invaded on the well-drained sites (15) thereby lowering the water table and reducing the available moisture for forage.




e) Thermal Infrared image (8 to 14 microns) Late summer



f) Radar image (1 to 3 cms.) Late summer

Figure 1. (cont.) Thermal infrared and micro wave imagery of the area seen in Figure 17 a,b,c, and d. Note the ease of detecting the poorly drained site (1), the moist site (2) and the well-drained or gravelly site (3) on the thermal infrared image. A natural spring, seen at (4) on photos (c) and (d), can also be seen in photo (e). Although the quality of microwave imagery does not permit detailed mapping of various range conditions, the gross boundaries of areas that may provide forage for livestock or wildlife can be drawn. The area within the inked box (photo (f)) corresponds to the area seen in Figure 17a,b,c, and d.

a) April 24, 1966

b) May 20, 1966

c) September 2, 1966

Figure 2. Kodacolor ground photographs of a sedge-rush-forbs community on a poorly drained site (1), and grasses, clover and forbs growing on a moist site (2). The corresponding aerial view of these plant communities is labelled 1 and 2 in Figure 17.


a) Panchromatic Scale 1/10,000


b) Aerographic Infrared Scale 1/10,000

c) Ektachrome Scale 1/30,000

d) Ekta-Aero Infrared Scale 1/30,000

Figure 3. Aerial photographs of various range conditons along Little Schneider Meadow, Bucks Lake Test Site. Note the ease of distinguishing between gravelly soil, supporting only annual grasses and forbs (A), and nearly pure Kentucky blue grass (B) on Infrared photo (b). Dense lush vegetation on moist sites (C) and (F) is readily seen in photos (b) and (d). Corn lily (Veratrum californicum), a poisonous plant for livestock, is found growing on moist sites in and around the willow clump at (D). Area (E) is a community of rushes, sedges, grasses and forbs. Note the channel erosion occurring between areas (A) and (B) and along the bank(circled) below Type C. Early detection and correction of erosion may save valuable range vegetation and soil from complete deterioration.


a) Panchromatic Scale 1/10,000 June 5, 1966


b) Aerographic Infrared Scale 1/10,000 June 4, 1966

Figure 4. Panchromatic and Aerographic Infrared (89B filter) aerial photographs of primary perennial range at Meadow Valley, California. Note the ease of detecting dense, lush wet meadow vegetation (A) on the infrared photo. A forage crop of alfalfa, clover and grasses (B), presently being irrigated, can readily be differentiated from the adjacent pasture (C) which remains saturated throughout the grazing season due to irrigation run-off and a high water table. Note the ease of detecting water holes, ponds, or streams (D) which may provide a potential source of irrigation water or drinking water for livestock.

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